

Relative Age, Maturation, Anthropometry and Physical Performance Characteristics of Players Within an Elite Youth Football Academy

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Abstract

A professional English football club with Category 1 academy status was investigated to determine the magnitude of relative age effects (RAE) within the club and explore between-quartile differences for somatic maturity, anthropometry and physical performances. Birth dates of 426 players from Under 9 to First Team were categorised into four birth quartiles (Q) and examined for RAEs. Additionally, data on 382 players (Under 11 to First Team) were obtained for somatic maturity, anthropometry, countermovement jump, sprint (10 and 30 m), agility T-Test, and Yo-Yo Intermittent Recovery Level 1 or 2 performance to determine between-quartile differences. Odds ratios revealed Q1 players were 6.0 times more likely to be represented than Q4 players. Multilevel modelling demonstrated similarities between-quartile for each variable across all age groups, though there was a tendency for Q4 players to outperform Q1 players between Under 11 and Under 18 groups. Strong RAEs exist within this club as well as a tendency to select players demonstrating advanced growth and/or maturity, with some indication that higher categorised academies in England may be at risk of amplified selection biases. Talent identification strategies in elite youth football should actively seek to adopt novel approaches to reduce selection biases and avoid wasted potential.

Keywords

Soccer, talent selection, birth date, highly trained, peak height velocity

Introduction

In the United Kingdom, youth football is a popular sport, where approximately 3.35 million children aged 5-15 years participate ¹. From this large pool of players, a subgroup of around 10,000 boys ² are recruited by elite teams or academies with the aim of eventually attaining professional status ³.

Football academies employ talent identification strategies, where multidisciplinary characteristics appear necessary for selecting players that have the potential to achieve elite performance ^{4, 5}; however, it is recognised that selection biases operate within the current system ⁶. Specifically, the relative age effect (RAE) is a well-documented phenomenon, characterised by an over-representation of players born towards the start of their respective selection year and is particularly already evident in elite teams ^{7, 8}. Recent evidence demonstrates this selection bias is evident from the earliest stages of formal recruitment (i.e. 9 years of age) ^{9, 10} and primarily concerns physical advantages (i.e. anthropometry and physical performances), though experience and psychological factors also appear pertinent ^{5, 8, 11}. Furthermore, elite youth teams also favour the selection of players advanced in biological maturity, with relatively younger players typically demonstrating this phenotype, which likely enables them to counteract age-related disadvantages ¹²⁻¹⁴. Recent evidence also suggests that biological maturation appears more discriminant than birth date for selection into academies ¹⁵.

In England, the RAE has been demonstrated within youth centres of excellence (now known as the Academy system) and national teams, whereby 49.1% of players (9 to 16-years-old) were born in the first quartile of the selection year ^{6, 16}. More recently, it was established that 48.6% of all Under 9 (U9) to U18 youth players from the academies of professional English clubs (League 1 and 2) were born in the first birth quartile ⁹. These findings highlight the robust nature of RAEs in English youth football, which corresponds to evidence from across Europe ¹⁷⁻¹⁹. During the 2011/12 season, there was a significant overhaul to the English Academy system, known as the Elite Player Performance Plan (EPPP) ³. Under the EPPP framework, several modifications were made to organisational practices which may have the potential to influence recruitment strategies. For example, a Category 1 academy, determined through a regular audit, has elite-level coaching and training facilities and they are permitted to recruit nationally ³. Pérez-Jimenez and Pain found that whilst RAEs were robust in all the Spanish

youth teams they investigated, the clubs deemed to be more successful, from big cities and/or with greater reputations for their youth teams tended to exhibit stronger RAEs²⁰. Therefore, it is plausible that since the inception of the EPPP, top categorised academies in England may demonstrate amplified selection biases compared to previous findings, though this is yet to be established.

Other pertinent research in elite youth teams has revealed that when controlling for chronological age and/or biological maturation, players born in different birth quartiles demonstrate a homogenous physical profile^{9, 12, 19, 21-23}. In addition, Skorski et al.¹⁹ observed superior physical performances in sprint and endurance performance for Q4 players in U19 and U21 groups, highlighting the potential for relatively younger players to demonstrate developmental advantages by the end of adolescence. However, these studies employed cross-sectional designs and, as such, no studies have utilised a mixed-longitudinal design to allow for multiple measures over a season. To this end, multilevel modelling has recently emerged as an appropriate technique to investigate RAEs, with Wattie et al. advocating the use of this technique to account for individual, environmental and task constraints²⁴. Individual variation in the timing and tempo of biological maturation processes confound anthropometrical and physical performance characteristics and this may occur sporadically throughout the season²⁵. Furthermore, the undeniable popularity of youth football in England, along with potential competition between Category 1 academies for player recruitment, underline important constraints that need to be considered in the investigation of selection biases under the EPPP framework in English academies¹¹.

Whilst RAEs have been researched extensively, there is a clear need for a contemporary investigation to clarify the impact of the EPPP on selection strategies adopted by a Category 1 academy. Furthermore, the application of multilevel modelling enables a comprehensive and more appropriate evaluation of between-quartile differences through permission of mixed-longitudinal data. Therefore, the aims of this study were twofold. Firstly, to investigate the prevalence of RAEs within each age group from U9 to First Team within one English professional football club, to identify if a systematic and amplified selection bias is evident; and secondly, to determine if somatic maturity, anthropometry and physical performance characteristics differ between birth quartiles in U11 to First Team groups.

Methods

Participants and design

To investigate the prevalence of RAEs, all 426 individual male players registered to one English professional football club between 2010/11 to 2017/18 seasons were examined. Players represented all eleven age groups within the football club from U9 to First Team (i.e. U9, U10, U11, U12, U13, U14, U15, U16, U18, U21 and First Team) and were born between 1975-2009. Records for U9 and U10 players could only be obtained for 2016/17 and 2017/18 seasons.

To investigate between-quartile differences in somatic maturity, anthropometry and physical performance characteristics, a total of 3192 data points from 382 individual players registered in U11 to First Team age groups between 2010/11 to 2016/17 seasons were examined. Players were born between 1975-2006. Corresponding data for U9 and U10 groups is not mandated as part of the EPPP testing battery ³, and was therefore not collected by the club. Data was collected on up to four testing periods per season, separated by approximately three months, for a total of seven seasons. Accordingly, players were followed for each season they were registered to the club and typically had repeated measurements (up to a maximum of four) for each season. All available individual player data was included, corresponding to mixed-longitudinal data. The total number of age groups that individual players had measurements recorded within are as follows: 1 (n=135), 2 (n=103), 3 (n=73), 4 (n=31), 5 (n=17), 6 (n=15), 7 (n=7). First Team testing was only completed until the end of the 2014/15 season.

An observational design was used to investigate the prevalence of relative age effects within the club and to ascertain between-quartile differences in somatic maturation, anthropometry and physical performances. All players were grouped into cohorts based on their chronological age, with the selection year in England spanning September in one year to August of the following year. All players within the academy typically completed between 3-8 (U9 to U11), 6-16 (U12 to U16) or approximately 16 hours (U18 to U21) of training per week, including competitive matches/tournaments. First Team players typically completed between 8-12 hours of training per week, including competitive matches. Players were only included in this study if they would qualify for home-grown status according to the Premier League, that is, players were registered to this club or any other club (prior to being recruited by this club) affiliated with The Football Association or Football Association Wales for three seasons or 36 months prior to their 21st birthday ³. All players at the club completed routine testing and provided signed consent as part of contractual agreements with the club to allow their anonymised data

to be used for research purposes. This study received ethical approval from the ethics committee at the University of Wolverhampton and permission from the club to use the anonymised data.

Procedures

All players completed standardised physical tests throughout the entire season (i.e. from pre-season to the end of the season), conducted by a team of trained exercise scientists that were employed by the club (as sports scientists) and The Premier League (as fitness testing assistants). All testing was completed indoors within a gymnasium and on an artificial turf pitch. At each testing session, all tests were carried out in the same sequence according to previously outlined recommendations by the Premier League³. Specifically, this involved: anthropometry, standardised jump-based warm up, jump test, standardised running-based warm up, sprint and agility tests, followed by Yo-Yo Intermittent Recovery Level 1 or 2. The jump and running-based warm ups were standardised and consisted of dynamic movements in the gymnasium and on the artificial pitch, respectively, each for 10 min. Players had a minimum of 5 min recovery between tests and at least 60 s passive recovery between attempts for sprint and agility tests. Players performed all tests in football boots, apart from the jump tests which were performed in running shoes. All players were familiarised with testing procedures and were provided with strong verbal encouragement throughout.

Anthropometry

All anthropometric measures were obtained according to The International Society for the Advancement of Kinanthropometry (ISAK) protocols²⁶ by ISAK accredited exercise scientists. Anthropometric testing was performed in the morning prior to training and in a t-shirt and shorts only. Standing height was assessed using a stadiometer (Model HR001, Tanita Leicester Height Measure) to the nearest 0.1 cm. Sitting height was assessed using an anthropometric box (height of 40 cm), as per ISAK guidelines²⁶, positioned at the base of the stadiometer, with measurement recorded to the nearest 0.1 cm. Leg length was calculated as the difference between standing height and sitting height. Body mass (Seca 22089, Hamburg, Germany) was assessed to the nearest 0.1 kg.

Physical performance

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157 Jump performance was assessed using the countermovement jump (OptoJump, Microgate,
158 Bolzano, Italy) test to the nearest 0.1 cm. The countermovement jump (CMJ) was performed
159 with players starting in an upright position, rapidly going into a squat position with knees flexed
160 at approximately 90 degrees, thereafter jumping maximally and landing with minimal knee
161 flexion. Hands remained on the hips to negate the influence of arm swing. The highest of three
162 jumps was recorded.

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164 Sprint performance was assessed through three maximal sprints of 30 m measured to the
165 nearest 0.01 s using timing gates (Brower Timing System, Utah, USA). Players commenced
166 each sprint from a standing start with their front foot 0.5 m behind the first timing gate. The
167 players began when ready, thus nullifying the influence of reaction time. The fastest 10 m split
168 time and 30 m time were recorded, which could have occurred in different trials.

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170 Agility performance was assessed using a modified version of the agility T-test ²⁷. Players
171 commenced each sprint from a standing start with their front foot 0.5 m behind the timing gate.
172 Subsequently, players ran forward 10 m, turned right 90 degrees around a cone and ran forward
173 5 m, turned right 180 degrees around another cone and ran forward 10 m, turned right 180
174 degrees and ran forward 5 m, turned right 90 degrees and ran 10 m to the start/finishing line.
175 Players began when ready, thus nullifying the influence of reaction time. The fastest recorded
176 time of three attempts to the left and right as well as the composite score determined using the
177 fastest time from each direction were recorded to the nearest 0.01 s.

178

179 Aerobic capacity was determined via the Yo-Yo Intermittent Recovery Level 1 (Yo-Yo IR1)
180 for U11 to U15 players and Level 2 (Yo-Yo IR2) for U16 to First Team players ^{28, 29}. Players
181 performed 2 x 20 m shuttles with a progressively increasing speed controlled by an audio
182 recording. Players had 10 s active rest between each 20-m shuttle run, which involved walking
183 2 x 5 m. Players ran until they failed to reach the finishing line on two occasions, with the final
184 score recorded as the distance of the last successfully completed shuttle.

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186 Relative age

Players birthdates were obtained from club records and categorised into birth quartiles (Q) within each age group according to the selection year spanning 1st September to 31st August; Q1= September-November, Q2=December-February, Q3=March-May, Q4=June-August.

Maturity status

Estimation of biological maturation was calculated for players in U11 to U16 groups only using Equation 3 of the non-invasive method developed by Mirwald et al. ³⁰, which estimates maturity offset within an error of ± 1 year 95% of the time. Age at peak height velocity (APHV) was subsequently calculated from chronological age and maturity offset which was updated at each testing session, where weight in Equation 3 denotes body mass reported in this study.

Statistical analysis

Relative age analysis was conducted for each age group (U9 to First Team) using odds ratios (OR) and 95% confidence intervals (95% CI) to calculate between-quartile comparisons, with Q4 as the referent group. Whilst previous research of RAEs has adopted chi-squared analysis ⁸, comparisons of birth data with the national population is deemed inappropriate and birth data for all registered youth football players within England was unavailable ³¹.

To investigate differences in somatic maturity, anthropometric and physical performance characteristics (dependent variables) across birth quartiles (independent variable), multilevel modelling was employed (MLwiN software package, v 3.02, Bristol University, Bristol, UK). This approach allows for the analysis of repeated-measures data with a different number of measures observed for each individual, which is the case in this dataset. Data was split according to standard age groups within the club (i.e. U11, U12, U13, U14, U15, U16, U18, U21, First Team). A model for each age group and each dependent variable (CA, somatic maturity, height, body mass, CMJ, agility composite, 10 m sprint time, 30 m sprint time and Yo-Yo IR1 or IR2) was created separately, allowing for each individual to be the level 2 variation (between-subject) and repeated measurements for each individual to be the level 1 variation (within-subject). Initially, differences for CA and somatic maturity (U11 to U16 only) across birth quartiles were examined. Subsequently, differences for all anthropometric (height and body mass) and physical performance (CMJ, agility composite, 10 m and 30 m sprint, Yo-Yo IR1 or IR2) variables were analysed, with CA and APHV included as covariates, as per previous research ^{33, 35}. In the U18, U21 and First Team groups, data were adjusted for CA

only, as the equation to derive maturity offset had not been validated in these older groups). Statistical significance was accepted at the 95% confidence level ($P < 0.05$).

Results

Relative Age Effects:

Table 1 shows the birth quartile distributions and odds ratio analysis for each age group. A greater proportion of players from the entire sample were born in the first quartile, with a decreasing number of players born between Q1 and Q4 (Q1: 43.4%; Q2: 29.8%; Q3: 19.5%; Q4: 7.3%). This trend was also evident within each age group, where the proportion of players born in Q1 ranged between 27.3 and 61.3%, whilst players born in Q4 ranged between 3.2 and 14.7%. Odds ratio analyses indicated that in the U9 group, there was a 19.0 times greater chance of being selected for players born in Q1 versus Q4. Thereafter, odds ratios were reduced in the U10 and U11 groups (OR: 3.0-4.8), but increased and remained high between U12 to U16 groups (OR: 7.3-10.3), and progressively decreased with each subsequent age group from U18 (OR: 4.2; 95% CI: 2.04-8.73) to First Team (OR: 2.3; 95% CI: 0.98-5.18). Analysis of the entire sample demonstrated Q1 players were 6.0 times more likely to be represented in this club than Q4 players (95% CI: 4.08-8.73).

Table 1 Survival analysis parameter estimates for the mean, standard error (SE) and 95% confidence intervals (CI) between birth quartiles, including the number of censored observations.

| Birth quartile | Mean | SE | 95% CI | N of players | N of censored | % of censored |
|----------------|------|-----|----------|--------------|---------------|---------------|
| 1 | 2.9 | 0.2 | 2.4, 3.3 | 151 | 47 | 31.1 |
| 2 | 3.4 | 0.3 | 2.9, 4.0 | 112 | 40 | 35.7 |
| 3 | 3.1 | 0.3 | 2.4, 3.7 | 68 | 26 | 38.2 |
| 4 | 3.4 | 0.6 | 2.3, 4.6 | 24 | 13 | 54.2 |

Anthropometrical Characteristics:

Table 2 presents somatic maturity and anthropometrical characteristics across birth quartiles for each of the age groups. In the U11 group, APHV was significantly higher for Q1 (13.4)

compared to Q4 (13.1) players. No other significant between-quartiles differences were observed for any age group. CA and APHV were significant covariates for height and body mass in U11-U16 groups, with CA significant in the U18 group and in the U21 group for body mass only.

Table 2 Number (%) of elite youth players from each birth quartile identified as dropout or retained from each age group within the club between 2010/11 and 2016/17 seasons

| | | Birth quartile | | | | Total |
|-----|----------|----------------|------------|-------------|-----------|-------------|
| | | Q1 | Q2 | Q3 | Q4 | |
| U11 | Dropout | 8 (14.8%) | 4 (12.9%) | 3 (15.8%) | 3 (30.0%) | 18 (15.8%) |
| | Retained | 46 (85.2%) | 27 (87.1%) | 16 (84.2%) | 7 (70.0%) | 96 (84.2%) |
| U12 | Dropout | 8 (14.5%) | 4 (9.8%) | 1 (6.3%) | 1 (14.3%) | 14 (11.8%) |
| | Retained | 47 (85.5%) | 37 (90.2%) | 15 (93.8%) | 6 (85.7%) | 105 (88.2%) |
| U13 | Dropout | 9 (16.7%) | 2 (4.4%) | 0 (0.0%) | 0 (0.0%) | 11 (8.7%) |
| | Retained | 45 (83.3%) | 43 (95.6%) | 21 (100%) | 6 (100%) | 115 (91.3%) |
| U14 | Dropout | 20 (35.1%) | 15 (31.3%) | 9 (37.5%) | 2 (28.6%) | 46 (33.8%) |
| | Retained | 37 (64.9%) | 33 (68.8%) | 15 (62.5%) | 5 (71.4%) | 90 (66.2%) |
| U15 | Dropout | 11 (22.0%) | 6 (15.8%) | 3 (15.0%) | 1 (16.7%) | 21 (18.4%) |
| | Retained | 39 (78.0%) | 32 (84.2%) | 17 (85.0%) | 5 (83.3%) | 93 (81.6%) |
| U16 | Dropout | 20 (45.5%) | 19 (48.7%) | 10 (50.0%) | 1 (16.7%) | 50 (45.9%) |
| | Retained | 24 (54.5%) | 20 (51.3%) | 10 (50.0%) | 5 (83.3%) | 59 (54.1%) |
| U18 | Dropout | 12 (34.3%) | 7 (21.9%) | 10 (58.8%) | 2 (40.0%) | 31 (34.8%) |
| | Retained | 23 (65.7%) | 25 (78.1%) | 7 (41.2%) | 3 (60.0%) | 58 (65.2%) |
| U21 | Dropout | 17 (73.9%) | 14 (51.9%) | 6 (37.5%) | 1 (25.0%) | 38 (54.3%) |
| | Retained | 6 (26.1%) | 13 (48.1%) | 10 (62.5%)* | 3 (75.0%) | 32 (45.7%) |

* denotes significant pairwise comparison vs Q1 (P<0.05).

Physical Performances:

Modelling indicated that physical performances across birth quartiles for each age group were similar, with several exceptions, which are shown in Table 2. Significant differences observed in U11-U18 groups indicated Q4 players outperformed other birth quartiles. In the First Team, Q4 players were inferior to all other birth quartiles for CMJ. There was a tendency for Q4 players to achieve the best physical performances across all variables in U11-U21 groups. CA

and APHV were significant covariates for physical performances, particularly in U13 and U14 groups.

Discussion

The aims of this study were to investigate the prevalence of relative age effects across different age groups; and secondly to explore between-quartile differences in somatic maturity, anthropometry and physical performance characteristics within each age group. To our knowledge, this is the first study to examine these themes over numerous seasons using participants from a professional English football club, with Category 1 academy status.

The current findings demonstrated strong RAEs upon entry to the academy (U9), as well as throughout adolescence (U12-U16) (Table 1). Despite the magnitude of RAEs decreasing with age, the proportion of Q4 players remained low throughout the entire club (i.e. 3.2-14.7%). Thus, our findings concur with literature demonstrating a systematic selection bias in favour of players born towards the start of the selection year^{22,32}. Previous data obtained from English centres of excellence indicate that around 49.1% of players (9 to 16-years old) were born in Q1, with only 9.9% from Q4⁶. Corresponding data from our study demonstrate that 44.0% and 6.6% of U10 to U18 players were from Q1 and Q4, respectively. Allowing for methodological differences between both studies, it is apparent that a selection bias due to relative age is firmly embedded in English elite-level youth football, with the percentage of selected Q4 players reducing over time. Moreover, our data indicate that odds ratios for each quartile in comparison with Q4 were typically greater across age groups, compared with a study of elite youth footballers registered to professional clubs during the 2012/13 season⁹. This finding appears to support the suggestion that Category 1 academies demonstrate a stronger penchant for RAEs²⁰. Thus, our findings suggest that top categorised academies under the new EPPP framework in England are particularly at risk of an amplified selection bias due to relative age, though further evidence is required. Between-quartile comparisons for somatic maturity revealed similarities for each age group (Table 2), yet a significant difference was observed for U11 players, with Q4 players demonstrating a lower APHV compared to Q1 peers (13.1 vs 13.4 years, respectively). Therefore, it would appear that in accordance with previous research, relatively younger players demonstrating advanced growth and/or maturation have an enhanced likelihood of being selected into an academy - particularly at the earliest stages of recruitment^{9, 12, 13}. Our findings also demonstrate lower APHV values for each corresponding

age group compared to those reported by Lovell et al.⁹, suggesting that in this Category 1 academy, selected players demonstrate advanced maturity compared with players selected by academies from lower-league teams in England. This corresponds with the aforementioned findings for RAEs, whereby higher categorised academies under the EPPP may also be at risk of an intensified selection bias due to advanced maturity. However, it is acknowledged that limitations exist with non-invasive methods to estimate APHV³³ and thus, our findings should be interpreted with caution. Specifically, whilst measures for individual players were typically obtained for multiple seasons and for several years in advance of estimated APHV, the method we adopted is reported to overestimate the timing of APHV and unlikely to differentiate players at the extremes of maturity (i.e. late and early maturers)^{34, 35}.

Corresponding to a similar APHV for players born in different quartiles, anthropometrical characteristics did not differ significantly in each age group, when adjusted for APHV and CA (Table 2). However, a closer inspection of players' height revealed the seemingly high importance of this characteristic for selection. Lovell et al.⁹ reported that players born in each quartile from each age group were typically between the 50th and 75th centile for height³⁶. However, allowing for methodological differences, our results revealed that players from U11 to U18 groups were typically around the 75th centile for height, with Q3 and Q4 players often residing above this. Most notable was the U14 group, where Q3 and Q4 players were around the 91st centile and between 91st and 98th centile, respectively. It has previously been established within youth ice hockey that RAEs are at least in part related to body size³⁷ and our findings corroborate that players' advanced height for their chronological age – particularly for relatively younger players – appears related to their selection. An association between height and the perception of domain-specific giftedness has previously been demonstrated in youth football³⁸ and our findings suggest this discrimination could be enhanced within a Category 1 academy and certain age groups within it (i.e. U14). Thus, additional research is warranted to determine if characteristics such as height are able to distinguish the players that are subsequently retained or released from a top categorised academy.

Physical performances were also typically similar between-quartiles for each age group with APHV as CA as covariates (Table 2), corresponding with previous studies in youth football^{9, 12}. Therefore, academies appear to systematically select players for each age group that demonstrate homogenous physical performances – irrespective of the birth quartile the players belong to³⁹. However, issues arise with this apparent selection strategy, specifically given that

there are many other predictors of talent required for football performance other than physical and physiological factors ⁴. Thus, many talented youth players that are competent in other factors related to elite performance may be overlooked by academies if they do not meet the apparent benchmark required for physical performances.

Previous studies have also identified practical advantages for Q1 versus Q4 players with regards to physical performances, highlighting benefits, albeit small, for being a relatively older player within an academy ^{9, 12}. In contrast, a novel finding of this study was that Q4 players tended to outperform other birth quartiles, with significant differences observed for several variables between U11 and U18 groups (Table 2). Specifically, Q4 players performed significantly better than Q1 players for Yo-Yo IR1 in U11, U13 and U14 groups and anaerobic running performance in U16 and U18 groups. The latter finding has previously been observed in the U16 and U18 German youth national teams ¹⁹, suggesting potential performance benefits gained by Q4 players towards the end of adolescence. Still, our findings are perhaps the first to demonstrate that in a highly selective group of players with largely homogenous anthropometrical profiles, Q4 players tend to achieve superior physical performances over Q1-born peers from childhood. This finding can be attributed to the methodological approach that was implemented. To the authors' awareness, our application of multilevel modelling to analyse between-quartile differences, is the first in the investigation of RAEs within elite youth football ⁵. Accordingly, when chronological age (and APHV) are accounted for within statistical analysis, Q4 players demonstrate physical performances at a higher percentile compared to Q1 players within this academy. An alternative explanation is that relatively younger players were afforded developmental advantages from childhood, thereby enabling them to achieve superior performances. Indeed, contemporary research has identified some potential benefits of being a relatively younger and/or later maturing player, often referred to as the 'underdog' hypothesis ^{40, 41}. In a recent study of academy footballers, Cummings et al. did not find an association between self-regulation and relative age, though the authors do not disregard that other 'underdog' advantages (e.g. motivation, decision-making, resiliency) could be cultivated in relatively older and/or later maturing players, possibly prior to academy selection (i.e. at grassroots) ⁴². In any case, our findings likely reflect a complex interaction with multiple factors, where further research is warranted through a comprehensive investigation of the underdog hypothesis, within elite academies as well as grassroots football.

Other findings revealed that in the First Team, Q4 players were significantly inferior compared to all other birth quartiles for CMJ performance (Table 2). This suggests that at the end of adolescence, players from other birth quartiles are able to make substantial improvements in CMJ performance and catch-up with Q4 players, likely through systematic training prescribed by the club ⁴³. On the other hand, this may be explained by the observation that, whilst not significant, Q4 players were also lighter than other birth quartiles, where enhanced fat-free mass is a predictor of CMJ performance towards the end of adolescence ⁴⁴. Still, it is possible that at the First Team level, once a minimum benchmark of physical performance is achieved, other factors related to elite performance are more important for enabling these players to be selected. Deprez et al. demonstrated that physical performances were able to distinguish players identified as retained or dropout from high-level youth teams in Belgium ⁴⁵, though corresponding data for all age groups within a club – particularly entry to the First Team - is yet to be elucidated and thus warrants further investigation.

Taken together, our findings demonstrate the recruitment strategy adopted by this club appears to be systematically limiting the entire talent pool of youth football players. Specifically, relatively younger and/or later maturing individuals are denied access to a high level training environment, which may in turn lead to premature dropout of football and thus a loss of potentially talented players ⁴⁶. Corresponding to previous research, it seems that organisational pressures (e.g. selecting players for immediate performance) outweigh the notion of recruiting and nurturing talent from a long-term perspective ⁴⁷, where the latter is central the EPPP framework ³. Therefore, we provide contemporary evidence highlighting the need for policy-makers within youth football to actively nullify selection biases due to relative age and biological maturity, whereby changes to current policies and/or additional research are required. This includes thorough consideration of club categorisation systems and the potential for their associated differences (e.g. recruitment opportunities) to perpetuate and even amplify selection biases. Additionally, there is a need ascertain the prevalence of RAEs at lower playing levels (i.e. grassroots), given that elite level players may be selected from an already biased pool of players ³¹, and thus may have key implications for targeting the reduction of RAEs. The availability of research documenting RAEs in youth football over the past decade ^{5, 8} appears to have had little impact on reducing selection biases, suggesting that more practical approaches are necessary. To this end, talent identification and selection processes in youth football would benefit by adopting holistic approaches ⁵, as opposed to an overreliance on transient physical characteristics that likely have limited long-term stability ⁴⁸. Recently, Mann

et al. demonstrated the potential application of age-ordered shirts to counteract RAEs⁴⁹, though the merit of this approach requires longitudinal investigation within an applied setting. Moreover, given that (skeletal) maturation is a stronger determinant of selection into elite youth teams¹⁵, this factor should also be considered when implementing approaches aimed at reducing this selection bias, where bio-banding may offer a practical solution⁵⁰. If successful, such approaches may subsequently enhance the attainment of the primary aim of youth development models (e.g. the EPPP), that is, converting a greater number of talented youth into high performing first team and international players³.

Limitations of this study relate to variability and lack of scope in the measurements utilised (i.e. tests and non-physical factors) and the method used to derive maturity. It is acknowledged that relevant measures were unable to be obtained in U9 and U10 groups, thus it is unclear which factors influenced RAEs in these groups. Additionally, this study reports the findings from one football club in England, thus the generalisability of findings should be interpreted with caution. The specific field tests and methodology utilised in elite football clubs to assess physical performances vary between countries and organisations, which makes comparisons between studies difficult. Furthermore, this study did not measure any other factors that are associated with RAEs (e.g. experience and psychological skills)¹¹, as well as performance, including technical/tactical, psychological and sociological competencies⁴. Moreover, this includes the absence of measures to ascertain maximal effort and/or motivation during physical testing, which may also explain the superior performances of Q4 players. Finally, issues regarding methods to assess maturation have been discussed above and in additional literature²⁵. Indeed, the limitations of the non-invasive method used in this study³⁰ were acknowledged, yet it was the most viable option to use within this study.

Conclusion

This study identified a strong relative age effect across the entire developmental pathway within this professional English football club, with a Category 1 academy. The magnitude of the RAE was particularly high at the entry-point (U9) as well as throughout adolescence (U12-U16). Multilevel modelling demonstrated that somatic maturity, anthropometry and physical performances were largely similar between-quartiles for all age groups. However, Q4 players tended to perform better than Q1 players in U11 to U18 groups, supported by several statistically significant differences. Furthermore, selected players from each quartile were

typically advanced in growth for their chronological age and/or demonstrated advanced maturity. Taken together, our findings highlight the robust nature of selection biases within this Category 1 academy and indicate that these may be amplified in higher categorised academies under the EPPP framework. Accordingly, this study provides contemporary evidence highlighting the need for policy-makers to actively seek ways to nullify selection biases. Future research is required to identify which playing level(s) should be targeted in order to reduce selection biases in youth football, where a number of practical solutions have recently been proposed. In turn, selection strategies adopted by youth football organisations will be more inclusive and may result in the identification of talented players that may otherwise go unnoticed.

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